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Development of Storm Water Quality Model for Ugep Urban, South-South Nigeria Using the Multiple Regression Approach

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Abstract: This research was aimed at the development of stormwater quality model for Ugep Metropolis. Physico-chemical and bacteriological characteristics of stormwater were obtained from ten sampling points, all within Ugep Metropolis for two months. The parameters examined were Temperature, pH, Electrical Conductivity, DO, COD, Total Phosphate, TSS, T.D.S, BOD_5, NO_2, NO_3, NH_4, Turbidity, THC and TCC. The model developed gave a good correlation of $R = 0.997$ and $R^2 = 0.994$ at 0.05 level of significance. The R square value of the regression model shows that NO_3, TURB, TP, THC, PH, TEMP, and DO accounted for 99.4% of the total variation in BOD_5 ($R^2 = 0.994$). The model is thus given as BOD_5, = -3.123–0.476NO_3–3.406TURB + 3.953TP + 14.449THC + 0.588pH–0.00005TEMP–0.371DO. It has been recommended that government should.

Keywords: Temperature, pH, Electrical conductivity

I. INTRODUCTION

The potentials of water and its quality as an economic resource and an essential component of human life cannot be overemphasized. The deterioration of water quality in major cities and urban areas due to population explosion, urbanization and industrialization results in large volume of direct effluent discharge into receiving streams. This invariably affects the water quality since these discharges introduce effluent above the assimilation capacity of these streams [1].

Land use in geographic areas that replenish groundwater and surface water resources is increasingly recognized as important factor affecting water quality and consequently, the health of human and ecological communities are sustained by these resources. For instance, release from commercial cum industrial facilities, agricultural run-off and wastewater leaching into the groundwater from residential septic systems can introduce a variety of pesticides into water supplies.

The formulation and use of indices has been strongly advocated by agencies responsible for water supply and control of water pollution. Water Quality Index (WQI) is defined as a rating reflecting the opposite influence of different water quality parameters [2].

The index serves as a tool for assessing the suitability and practicability of water quality programs. Water is said to be portable if it is fit to be ingestible. Hence, to get the quality of water, the quantity must be sampled. Sampling is the process of obtaining data for physical, chemical and bacteriological parameters for analysis.

The following parameters were selected for this study: Dissolved Oxygen, pH, Electrical Conductivity, NO_2, NO_3, NH_4, TP, Total Suspended Solids, Total Dissolved Solids, Total Heterotrophic Count, Total Coliform Count, BOD_5, Turbidity, Chemical Oxygen Demand, and Temperature.

The objectives of the study were to develop a storm water quality model for Ugep Urban, to determine the bacteriological and physico-chemical qualities of storm water in Ugep Urban, and to determine the level of pollution contributed by stormwater to receiving streams around the study area.

II. MATERIALS AND METHODS

Description of Area of Study

Ugep is a community in Yakurr Local Government Area of Cross River State – Nigeria. The area lies between latitude 04°55’35’’N; longitude 09°21’00’’E and latitude 04°58’31’’N; longitude 09°23’10’’E. The area has the highest population in the Local Government Area.

The atmospheric condition of the area is relatively high with annual mean minimum and maximum temperatures ranging from 21°C to 32°C and an average relative humidity of 72 percent. The area consists of two seasons, the wet and dry season. The wet season last from April to October with maximum rainfall in the month of June and a brief August break around the second week of the month. The dry season starts from November to March.

The topography of the area is relatively stable with a slope of about 1:500. The area has an annual rainfall of 1820 mm to 3000 mm of which more than 90% of this falls during the rainy season. The area is covered by sand, clay, gravel, silt and little deposit of metamorphic and sedimentary rocks. Hydrologically, the area consists of two sub aquifer units. The upper is generally less than 30 m and the lower is a sandy zone. The entire hydrological system consists of these two sub units termed Coastal Plain and Sandy aquifers respectively [3].

Culturally, the people are known to have many interesting cultural heritage and value like the internationally celebrated LEBOKU Festival. Not less than 50% of the inhabitants are farmers due to the fertile nature of their land [4].

Commercially, the area is a central business district (CBD) of its own because of its strategic location and good road network connecting the northern part of Nigeria to the East and western parts. It also serves as a focal point of commercial activities to the three (3) Local Government Areas of the State around them (Obubra, Abi and Biase) in the North, West and South respectively.

Global Perspective of Water

Water is prominent on the list of global crisis that are predicted to present major challenges to human populations at scales ranging from local to global. In the coming decades, water is thus expected to acquire an increasingly important position on the global agenda. Even today, water related human morbidity and mortality, which results from widely divergent levels of both water quality and quantity, is already widespread, and almost 80% of the global population faces exposure to high threat levels of water insecurity [5].

The impacts of water shortages are particularly acute in the developing world, where rising populations and climate change are expected to cause severe water shortages for one-third of the population in this century [6]. Yet, despite such findings, awareness of the global water crisis is far from commensurate with the scale of the problem. One reason is that the people suffering the most from this water and sanitation crisis are poor people in general and poor women in particular who often lack the political voice needed to assert their claims to water [7].

Additionally, the mainstream academic community involved with hydrology and water has largely ignored the issue and holds widely divergent opinions regarding whether and when the world will run out of water [6].

But according to one analyst, broad agreement does exist that there will be significantly increasing water scarcity that will turn water into key, or the key limiting factor in food production and livelihood generation for poor people virtually throughout rural Asia and most of Africa [8].

Our understanding of global water issues can be increased by examining three sub-issues such as safe drinking water, pollution and degradation; and water scarcity [6].

Safe drinking water implies that water is largely free from impurities and microorganisms that frequently cause disease or death. Unsafe drinking water significantly limits human progress. Close to half of all people in developing countries suffer from health problems caused by water sanitation deficits at any given time [7]. To address this burden, the WHO outlines measures, such as providing access to sufficient quantities of safe water, providing facilities for disposal of sanitary waste, and introducing sound hygiene behaviors [9].

Water scarcity refers to a situation when the water supply is inadequate in relation to the water demand for basic human and ecological necessities, including the production of food and other economic goods. Scarcity is the principal component of the three fold water crisis because it can drive or exacerbate both access and pollution [6].

The Human Development Report highlights the social rather than environmental origins of water scarcity; the heart of the global water crisis is rooted in power, poverty and inequality, not in physical availability [7,10].

Both surface and ground waters receive urban pollution for wastewaters and sewage and chemicals from agricultural run-off. As well, declining and degraded water supplies have led to conflicts among different users, such as between pastoralists and farmers, upstream and downstream users, humans and wild life, among others [11].

Any number of water quality measurements can serve, and have been already used, as indicators of water quality. However, there is no single measure that can describe overall water quality for any body of water. As such, a composite index that quantifies the extent to which a number of water quality is measured deviate from normal, expected or ideal concentrations maybe more appropriate for summarizing water quality conditions across a range of inland water type and overtime [12].

Although there is no globally accepted composite index of water quality, some countries and regions have used, or are using, aggregated water quality data in the development of water quality indices. Most water quality indices rely on expected concentrations and some interpretation of good versus bad concentrations [13]. Parameters are often weighted according to their perceived importance to overall water quality and the index is calculated as the weighted average observations of interest.

Pesce and Wunderlin [14] compared the performance of three water quality indices on the Suquia River in Argentina. All three indices were calculated using observations for 20 different parameters that were normalized to a common scale according to observed concentration and expected ranges.

The objective and the subjective indices were then calculated as a function of the normalized values, the relative weight assigned to each parameter and in the case of the subjective index, a constant that represented the visual impression of the contamination level of a monitoring station.

The third index, the minimal index, was calculated as the average of the normalized values for only three parameters (dissolved oxygen, conductivity, and turbidity). The study reported that the minimal index was well correlated to the objective index, and both water quality indices were generally correlated to the measured concentrations of different parameters.

Beryback M et al. [1] defined water quality as a term use to express the suitability of water to sustain various uses or processes.

Continental water bodies which include the following water, lakes, reservoirs etc. are all interconnected by the hydrological cycle with many intermediate water bodies, both artificial and natural. Wetlands such as floodplains, alluvial aquifers and marshes have characteristics of hydrological intermediates between those rivers. It is essential that all available data of hydrological cycle be included in the water quality assessment because water quality is greatly affected by the hydrology of a water body.

Sample Location

Ten (10) sampling point were chosen for the research work, all within the study area. The Table 1 below shows the samples location in a clear and comprehensive manner.

Table 1. Sample location.

S/No	Code	Location
		Ugep urban
1	S1	Hospital Road
2	S2	Obioku Street
3	S3	Uyo Street
4	S4	Kekonkola road
5	S5	Former Community Bank Road
6	S6	Idomi Road
7	S7	Ediba Road
8	S8	Lekpankum Street
9	S9	Usajah street
10	S10	Ekokol Road

Sample Collection

A total of twenty (20) samples were collected from the above location in Table 1 within the periods of two months, ten (10) samples were collected in the month of June and ten (10) in the month of September. The samples collected, were used to assess the physico-chemical and bacteriological qualities of the stormwater.

The samples were collected in a clean one (1) litre inert plastic bottle, which were rinsed with distilled water before use (collection).

The bottles were held at its base downward and lower one foot into the water, the cover were removed with the other hand, and the bottle was immediately cocked after filling or collection of each sample and put into the cooler containing ice block, in order to maintain the atmospheric condition with a minimum temperature range of 4°C.

The bottles were properly labelled and analysis was carried out within the period of (48) hours after collection.

Analysis of Samples

The parameters analyzed to develop the storm water quality model for the area (Ugep metropolis) are broadly divided into three categories such as physical, chemical and biological characteristics. Such as TEMP, TURB, pH, E.C, TSS, TDS, DO, BOD_5, COD, NO_2, NO_3, PO_4, NH_4, TCC, THC.

The analysis were carried out for the above water quality influencing fifteen (15) parameter with concerning unit and test methods discussed below.

III. RESULTS AND DISCUSSION

Table 2 shows the bivariate correlation analysis between the variables while Tables 3-17 show comprehensive results of the physico-chemical and bacteriological analysis of water samples collected from the study area Ugep urban at different sampling periods.

Table 2. Bivariate correlation analysis between the variables.

	BOD_5	**Temp**	**pH**	**DO**	**COND**	**TS**	**TDS**	**NO_2**	**NO_3**	**NH_4**	**COD**	**TP**	**THC**	**TURB**
BOD5	1.00													
Temp	0.44	1.00												
pH	-0.25	-0.72*	1.00											
DO	0.40	0.17	-0.21	1.00										
COND	-0.40	-0.53	0.55	-0.32	1.00									
TS	-0.67*	-0.13	0.08	-0.76*	0.18	1.00								
TDS	-.053	-0.12	-0.18	0.22	-0.35	0.26	1.00							
NO_2	-0.05	-0.53	-0.02	0.07	-0.01	0.02	0.29	1.00						
NO_3	-0.17	0.06	-0.44	0.44	0.16	-0.21	0.28	0.19	1.00					
NH_4	0.39	0.09	-0.28	0.44	-0.47	-0.61	0.05	-0.04	0.21	1.00				
COD	0.60	0.27	-0.07	0.51	-0.06	-0.54	-0.51	-0.40	0.19	0.41	1.00			
TP	0.16	0.68*	-0.69*	0.11	-0.25	0.04	0.06	-0.49	0.47	0.13	0.33	1		
THC	0.34	0.95*	-0.59	0.22	-0.51	-0.04	0.01	-0.59	-0.06	-0.08	0.26	0.7	1.00	
TURB	-0.71*	-0.31	0.56	0.71*	0.47	0.75*	0.09	0.33	-0.38	-0.61	-0.47	0.70	-0.156	1.00

Table 3. pH values.

Location	**Sampling Periods**		**MEAN**
	June	**September**	
	1	2	
S1	6.44	6.59	6.515
S2	6.47	6.4	6.435
S3	6.76	6.8	6.78
S4	6.57	6.84	6.705
S5	6.61	6.48	6.545
S6	6.57	6.42	6.495
S7	6.35	6.3	6.325
S8	6.71	6.64	6.59
S9	6.54	6.44	6.49
S10	6.2	6.04	6.12

Table 4. B.O.D_5 values.

Location	**Sampling Periods**		**Mean**
	June	**September**	
	1	2	
S1	0.02	0.05	0.035
S2	0.01	0.06	0.035
S3	0.01	0.03	0.02
S4	0.02	0.04	0.03
S5	0.01	0.04	0.025
S6	0.03	0.05	0.04
S7	0.03	0.04	0.035
S8	0.01	0.06	0.035
S9	0.02	0.04	0.03
S10	0.04	0.05	0.045

Table 5. T.D.S values.

Location	Sampling Periods		Mean
	June	September	
	1	2	
S1	0.9	0.09	0.495
S2	0.75	0.85	0.8
S3	0.4	0.09	0.245
S4	0.2	0.1	0.15
S5	0.4	0.21	0.305
S6	0.6	0.11	0.355
S7	0.38	0.04	0.42
S8	0.1	0.04	0.07
S9	0.1	0.1	0.1
S10	0.34	0.09	0.43

Table 6. Electrical conductivity values.

Location	Sampling Periods		Mean
	June	September	
	1	2	
S1	98.1	94.4	96.23
S2	26.5	24.9	25.7
S3	117	119.7	118.2
S4	114	196.7	155.5
S5	104	107.4	105.8
S6	101	104	102.4
S7	171	150.3	160.4
S8	137	123.6	130.4
S9	28.4	25.6	26.98
S10	11.2	10.13	10.64

Table 7. Temperature values.

Location	Sampling Periods		Mean
	June	September	
	1	2	
S1	26.7	24.9	25.8
S2	26.7	24.9	25.81
S3	26.1	24.8	25.45
S4	26.2	25	25.6
S5	26.4	25.2	25.8
S6	26.3	24.9	25.6
S7	26.5	25.1	25.8
S8	26.6	25.2	25.9
S9	26.6	25.2	25.9
S10	27.2	24.8	26

Table 8. Turbidity values.

Location	Sampling Periods		Mean
	June	September	
	1	2	
S1	0.19	0.32	0.255
S2	0.16	0.27	0.215
S3	0.24	0.32	0.28
S4	0.3	0.37	0.335
S5	0.24	0.34	0.29
S6	0.18	0.32	0.25
S7	0.15	0.24	0.195

S8	0.19	0.17	0.18
S9	0.18	0.18	0.18
S10	0.24	0.14	0.19

Table 9. Dissolved oxygen values.

Location	**Sampling Period**		**Mean**
	June	**September**	
	1	2	
S1	0.36	2.08	1.22
S2	0.37	2.29	1.33
S3	0.4	2.03	1.015
S4	0.3	1.28	0.79
S5	0.25	1.3	0.775
S6	0.41	1.6	1.005
S7	0.38	1.99	1.185
S8	0.47	2.24	1.355
S9	0.39	1.83	1.11
S10	0.39	2.08	1.235

Table 10. Ammonium values.

Location	**Sampling Period**		**Mean**
	June	**September**	
	1	2	
S1	0.06	0.067	0.0645
S2	0.08	0.171	0.124
S3	0.11	0.069	0.0895
S4	0.09	0.089	0.09
S5	0.07	0.066	0.069
S6	0.09	0.085	0.0865
S7	0.07	0.0133	0.1025
S8	0.11	0.088	0.097
S9	0.16	0.084	0.12
S10	0.05	0.147	0.0995

Table 11. C.O.D values.

Location	**Sampling Period**		**Mean**
	June	**September**	
	1	2	
S1	7	5.4	6.2
S2	6.5	4.4	5.45
S3	8.2	4.9	6.55
S4	9	4	6.5
S5	4.6	3.3	3.95
S6	7	4.7	5.85
S7	6.4	6.7	6.55
S8	7.6	6.4	7
S9	9.2	5.1	7.15
S10	6.2	7.8	7

Table 12. Phosphate values.

Location	**Sampling Period**		**Mean**
	June	**September**	
	1	2	
S1	0.19	0.076	0.132
S2	0.18	0.077	0.129
S3	0.14	0.093	0.115

S4	0.16	0.106	0.135
S5	0.15	0.086	0.117
S6	0.14	0.101	0.119
S7	6.4	0.063	0.133
S8	0.14	0.103	0.12
S9	0.17	0.069	0.122
S10	0.22	0.076	

Table 13. Total heterotrophic counts (THC).

Location	**Sampling Period**		**Mean**
	June	**September**	
	1	2	
S1	0.2	0.2	0.2
S2	0.1	0.2	0.15
S3	0.1	0.2	0.15
S4	0.2	0.21	0.205
S5	0.1	0.3	0.2
S6	0.1	0.31	0.205
S7	0.2	0.1	0.15
S8	0.1	0.11	0.105
S9	0.1	0.2	0.15
S10	0.1	0.2	0.15

Table 14. Total suspended solids (TDS) values.

Location	**Sampling Period**		**Mean**
	June	**September**	
	1	2	
S1	0.012	0.018	0.015
S2	0.01	0.013	0.0115
S3	0.006	0.019	0.125
S4	0.005	0.019	0.024
S5	0.004	0.017	0.0105
S6	0.006	0.017	0.115
S7	0.003	0.015	0.009
S8	0.003	0.019	0.011
S9	0.003	0.016	0.0095
S10	0.004	0.015	0.0095

Table 15. Nitrite values.

Location	**Sampling Period**		**Mean**
	June	**September**	
	1	2	
S1	0.269	0.025	0.147
S2	0.251	0.033	0.284
S3	0.145	0.032	0.088
S4	0.153	0.045	0.099
S5	0.128	0.025	0.076
S6	0.139	0.032	0.092
S7	0.1354	0.045	0.01995
S8	0.173	0.038	0.105
S9	0.158	0.032	0.098
S10	0.186	0.036	0.111

Table 16. T.C.C values.

Location	Sampling Period		Mean
	June	September	
	1	2	
S1	0.25	0.938	0.594
S2	0.179	0.936	0.557
S3	0.254	0.379	0.316
S4	0.22	0.277	0.248
S5	0.301	0.934	0.616
S6	0.248	0.934	0.591
S7	0.185	0.932	0.558
S8	0.193	0.927	0.56
S9	0.254	0.922	0.588
S10	0.357	0.138	0.247

Table 17. Parameter estimates for stepwise multiple linear regression.

Parameter	B	S.E	t	p value
Constant	-3.123	0.52	-6.06	0.026
NO_3	-0.476	0.44	-1.09	0.389
TURB	-3.406	0.32	10.6	0.009
TP	3.953	1.5	2.64	0.119
THC	14.449	6.02	2.4	0.138
pH	0.588	0.09	6.5	0.023
Temp	-5E-05	0.01	-0.63	0.593
DO	-0.371	0.09	-4.27	0.051

Table 16 shows the parameter estimates for stepwise multiple linear regression. The results showed the bivariate relationship between each of the variables. There was a significant negative relationship between BOD_5 and TSS ($r=-0.67$, $p<0.05$) and TURB ($r=-0.71$, $p<0.05$). There was also a significant negative relationship between pH and Temperature ($r=-0.72$, $p<0.05$).

TSS was significantly negatively related with DO ($r=-0.76$, $p<0.05$). The relationship between THC and TP was significantly positive ($r=0.70$, $p<0.05$). DO showed significant negative relationship with TURB($r=-0.71$, $p<0.05$) while the results obtained between TSS and TURB was significantly positive($r=0.70$, $p<0.05$), TP and Temperature ($r=0.68$, $p<0.05$).THC and Temperature ($r=0.70$, $p<0.05$), TURB and TP ($r=0.70$, $p<0.05$). Results obtained for other variables were insignificant (>0.05),

The result of multiple linear regression as presented in Table 15 shows that the NO_3, TURB, TP, THC, pH, temperature and DO accounted for 99.4% of the total variation in BOD_5 ($R^2=0.994$). NO_3 did not show a significant contribution to BOD_5 ($\beta=-0.476$, t calc.= -1.09 = -1.09, $p<0.05$) although it had a negative contribution. TURB had a significant negative contribution to BOD_5 ($\beta=-3.406$, t calc. =-10.58, $p<0.05$) which means that the level of BOD_5 will increase significantly whenever there is an increase in TURB.

Also pH revealed a significant positive contribution to BOD_5 ($\beta=-0.588$, t calc.=6.50, p=0.023, $p<0.05$), this means that as pH increases, BOD_5 will increase significantly. The contribution of other variables (TP, THC, Temperature and DO) were all insignificant ($p<0.05$). The model developed for predicting BOD_5 is therefore: $BOD_5 = - 3.123 – 0.476\ NO_3 – 3.406TURB + 3.953TP + 14.449THC + 0.588pH – 0.00005Temp. – 0.371\ DO$.

To assess the adequacy of this model in predicting BOD_5, analysis of variance was used. The result of analysis of variance as shown in Table 18 showed F calculated value of 47.01 and p=0.021, $p<0.05$. Based on these results, the model can be judged to be adequate in predicting BOD_5.

Table 18. ANOVA results for the stepwise multiple linear regression.

	Sum of squares	**Df**	**Mean square**	**F**	**P value**
Regression	0.087	2	0.012	47.01*	0.021
Error	0.01	7	0.0003		
Total	0.087	9			

*significant at 0.05 level of significance ($p<0.05$)

IV. CONCLUSION AND RECOMMENDATION

This study was conducted to develop a stormwater quality model for Ugep metropolis. BOD_5 was regressed as a dependent variable against the aforementioned physico-chemical water quality parameters. The result of the model revealed that NO_3, TURB, TP, THC, pH, TEMP, and DO accounted for 99.4% of the total variation in BOD_5 ($R^2 = 0.994$). NO_3 did not show any significant contribution to BOD_5 ($\beta= -0.476$, t calc.= -1.09,$p>0.05$). TURB had a significant negative contribution to BOD_5 ($\beta= -3.406$, t calc. = -10.58, $p<0.05$) which means that the level of BOD_5 will increase significantly whenever there is an increase in TURB. Also, pH revealed a significant positive contribution to BOD_5 ($\beta=0.588$, t calc.=6.50, p=0.023, $p<0.05$): meaning that as pH increases, BOD_5 also increases significantly. The contribution of the other variables (TP, TEMP, THC, and DO) were all insignificant ($p>0.05$). The model developed for predicting BOD_5 is therefore: $BOD_5 = -3.123 - 0.476NO_3 - 3.406TURB + 3.953TP + 14.449THC + 0.588pH - 0.00005TEMP - 0.371DO$. In assessing the adequacy of this model in predicting BOD_5, analysis of variance was used. It shows F calculated value of 47.01 and P = 0.021, $p<0.05$. Based on these results, the model could be judged to be adequate in predicting BOD_5.

Based on the findings of this research, it is recommended that:

- People living within the study area should be encouraged to construct soak away/septic tanks to avoid indiscriminate sewerage.
- Open and free-range defecation should be outlawed so as to check and, or reduce the high rate of bacterial contamination of the environment.
- Analysis should be carried out periodically to monitor the level/rate of contamination of the study area.

Further studies should be carried out within the study area to determine the impacts of other parameters not considered in this study.

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